Report of the Workshop on Barley Genetic Stocks – Global Use and Potential at the 11th International Barley Genetics Symposium Held in Hangzhou, China, April 18th, 2012.

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The workshop was held on Wednesday night April 18th, 2012 in the 'First World Hotel', Hangzhou, China and about 80 delegates participated. Udda Lundqvist chaired the workshop and welcomed the participants. This workshop was initiated by the users of Barley Genetic Stocks to make recommendations on future directions to the International Organizing Committee (IOC) of the International Barley Genetics Symposium (IBGS). The history and current status of Barley Genetic Stocks were outlined and discussed.

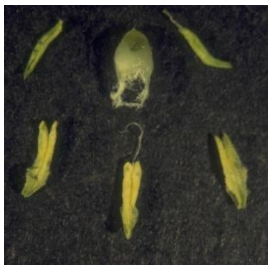
To set a frame for the workshop, *Udda Lundqvist* made a PowerPoint presentation to delegates on historic and current activities involving barley genetic stocks.

- Definitions of Barley Genetic Stocks (BGS):
  a) Natural and induced mutations,
  b) Chromosome aberrations, translocations, inversions etc,
  c) Ploidy changes: tetraploids, haploids, aneuploids, trisomics. telotrisomics,
  d) Cytoplasmically inherited traits,
  e) Multiple genetic marker stocks, and
  f) Isogenic and backcrossed-derived lines.
- Production of Barley Genetic Stocks (BGS):
  a) Accumulated over many decades, nearly 100 years,
  b) Extensive and substantial investments of time and resources,
  c) Intensive observations made with much and large enthusiasm, and
  d) Numerous and extensive genetic research studies were conducted.
- Conservation of Barley Genetic Stocks (BGS).
  a) Many of the genetic stocks produced and studied have been incorporated in genebanks or are maintained in research facilities worldwide, and
  b) Descriptions and characterizations of stocks are mostly stored in national databases.
- Today's use of Barley Genetic stocks (BGS).
  a) Gene cloning projects,
  b) Location of gene analogues,
  c) Valuable research tools for insights to the biology of crop plants, and
  d) Increasing diversity for barley breeding.

- Finally some actual and important questions about the future of Barley Genetic Stocks (BGS).
  a) The maintenance and quality assurance as a task worldwide.
  b) The need of backup duplications.
  c) Responsibility of the home institute for regeneration and security control.
  d) Realistic and cost-efficient approach as a joint system for conservation on a global level.
  e) Assigning a global BGS coordinator.
  f) A global advisory board to be appointed.
  g) Establishing a Barley Genetic Resource committee by the International Genetic Symposium (IBGS)
  h) A strategy for global funding.

After this introduction *Udda Lundqvist* stressed the need to focus on the future use and maintenance of barley genetic stocks. Several speakers were asked to present their opinion of the importance of the BGS. As a keynote speaker *Takao Komatsuda*, Tsukuba, Japan, presented information on BGS structure using the six-rowed spike 1 (*vrs1*) gene as an example. He stressed the importance of precision in nomenclature and showed historic developments. The six-rowed spike 1 gene was cloned by his research group. It is a homeodomain-leucine zipper and its expression is strictly localized in the lateral spikelet primordia of immature spikes, suggesting that the *VRS1* protein suppresses development of lateral spikelet. He demonstrated polymorphism in mutant lines; splicing mutations in *Vrs1*; deletion, duplication and insertion at *Vrs1* in the *hex-v.15* mutant; deletion of *Vrs1* as indicated by Polymerase Chain Reaction (PCR9; natural and induced mutations in *Eibi1* ABCG transporter essential for retention of leaf water; an *Eibi1* ABCG transporter mutation found in the rice *Tos17* mutant panels; a table of descriptions of mutational events detected in *Vrs1* mutants and an image of alleles at the *vrs1* locus compared with their mother cultivars. *Takao Komatsuda* highlighted the importance of having access to many alleles of the same locus and the important role of conserving these resources as barley genetic stocks for future access.

The second speaker was *Nils Stein*, IPK, Gatersleben, Germany. He started by bringing a few points to the attention of the attendees. Mutants are needed to confirm gene function. For a long time the availability of old genetic resources was a limiting factor, but this has changed. Nils Stein has mainly used Bowman near isogenic lines (NIL) through ERA-PG, a European funded collaboration between the United Kingdom, Germany and Italy. The main idea was to use genetic resources and develop the use of Illumina SNP (single nucleotide polymorphism) chip to make possible mapping all mutants. A few mutants were selected as examples for studies of gene cloning. Nils Stein outlined his use of different mutants and his strategies. He



also stated that the lack of interest in mutants by breeders is based on ignorance of this resource. The morphological mutants isolated by earlier researchers have very strong phenotypes because they affect the mainly visual traits e.g. spike type, straw length and color, etc. Today we have the same request for different sets of traits from those formerly focusing on by plant breeders. Specific genes should be cloned to improve our understanding of them. Basic science and plant breeding have the same interest in this respect. Nils Stein stressed secondly that the barley community must be aware of that scientific progress is much faster now-a-day. The rate of progress will change drastically when the barley genome is sequenced, cloning of genes will happen much sooner than expected. Scientists studying gene discovery of other crops e.g. rice, Brachypodium etc. will move into barley as a model for their primary interests, and they will be rather strong competitors. Therefore it would be very reasonable for the barley community to strongly coordinate work, e.g. several groups could work simultaneously with the same gene to get faster results. Why should not all the genes be cloned? Nils Stein suggested gathering all groups and making global efforts in order to gain time. It is also of great importance to organize all allelic information available.

The third speaker *Mats Hansson*, Carlsberg Laboratory, Copenhagen, Denmark, presented his vision of the use of barley mutants obtained from genetic stock collections. He guided using PowerPoint slides workshop participants through his studies of several mutant groups such as early maturity, early flowering, dwarfs, brachytic, erect growth habit and chlorophyll biosynthesis. He presented an overview of genes identified with the help of mutants. The most important one recently identified is the *mat-a* or *eam8* gene (early maturity 8) published in PNAS by Zhakhrabekova *et al*. 2012. He high lightened especially the work with the xantha seedling group and illustrated the close links between genetics and biochemistry showing the dependency on having access to a number of correct mutants in order to study the function and structure of the corresponding proteins. By this fundamental processes as energy metabolism in the plant cell can be addressed. He raised the question 'what is important for us with respect to the mutant collections?' Based on from mutant studies, especially results with *xantha-g* and *xantha-h* genes, he concluded that we need many alleles, gene identification (the correct candidate gene should contain all allelic mutations) and biochemical analyses (every mutant contributes to the understanding of the protein interactions). Finally he listed a number of areas of interest for collaboration: early maturity, vernalization, senescence. straw length, lodging resistance, chlorophyll and heme biosynthesis, waxy biosynthesis and malt quality.

The fourth speaker *Michele Stanca*, Fiorenzuola, Italy, did not want to present a lot of mutants again as he already did so in his talk earlier in the week, but he wanted to stress some items of importance and strategy. Mutants are mutants and as such are of large importance for both science and plant breeding. However mutants cannot be used directly in breeding work as they often have some negative characters. Mutants can be applied in pre-breeding to create the

barley plant in the future. Barley has so many advantages that the barley community can easily compete with other crop researchers if we use the mutants in a proper way. Stanca also mentioned an important group of double mutants in which one mutant causes problems that can be complemented by a second one. As example he referred to the laxatum-a gene. He also stressed the importance of Barley Genetics Newsletter which contains many important basic and applied scientific articles. Finally he suggested giving a proposal to the International Organizing Committee (IOC) to integrate the barley genetic stock workshops into the International Barley Genetics Symposium (IBGS) program with the first full effect in 2016 at the 12th IBGS in USA, if he gets the support of the BGS community. **Full support was given by the workshop that Michele Stanca, one of the IOC members, should make this request.**

The fifth speaker *Pat Hayes*, Corvallis, Oregon, USA, explained his introduction to the use of mutants in Oregon of the R.I. Wolfe's Multiple Marker Stocks, and that he initially did not know what to do with them when the seeds landed on his desk. A student produced a number of double haploids (DH) for a Masters degree project based on this material. Without having any specific intentions with this material, it has become a remarkable success and was widely applied in research and practical plant breeding. All the different combinations of alleles that started as an instructional and educational tool have become the basis for increased development. The material is used in many places and for many purposes. Practical breeders can certainly find the value of these stocks. *Pat Hayes* stressed that this is the core point concerning the mutant collections, we cannot foresee its future potential and its complete usage, but the material must be conserved. He also stressed his concern for the long term conservation of stocks which are now kept in his deep freezers. He really relies on his colleagues to maintain them and conserve them properly. It is their duty!

The sixth speaker *Gary Muehlbauer*, St. Paul, Minnesota, USA, referred to the tillering mutants as an important source for developmental studies and as a source of alleles that have been cloned. When *Udda Lundqvist* asked concerning the disease resistant genes, Gary Muehlbauer emphasized the high importance of this group and high lightened Brian Steffenson's extensive research work, especially on resistance to stem rust (*Rpg* loci) as an example.

The seventh speaker *Robbie Waugh*, Dundee, Scotland, high lightened the tilling projects and the Bowman near isogenic lines (NIL). Nearly 1000 mutants are characterized and introduced by backcrossing into the Bowman genome. Gene functions are published. The access to and use of multiple alleles has been necessary to characterize the gene functions. Mutants are a scientific tool, they should be studied to understand and manipulate the genetics of economically and agronomically important traits, e.g. the use of awnless barley or improvement of traits as lodging resistance, straw breakage and spike loss. But we need funding for such investigations. *Waugh* stressed the importance of mutant collections as reference material, and that they are very valuable series for testing allelism. He also stressed the importance of having many mutants in the same gene and in the same background genotype. Then it is easier to identify genes and validate their function.

The last speaker was *Morten Rasmussen* from NordGen (Nordic Genetic Resource Center), Sweden. He presented important points from a genebank perspective in connection with several PowerPoint slides. He stressed and explained the user statistics from Nordgen concerning barley Precise Genetic Stocks (PGS) in a diagram where more than 50% of barley accessions are located at NordGen. PGS are a significant and important part of the scientific use of NordGen collections and listed the different types of the stocks. He also showed figures on number of seed requests, their purposes and request countries during the last years. He then presented the European Gene Bank Integrated System (AEGIS) and explained the focus on endangered Precise Genetic Stocks in a European Commission Seven Frame Program (FP7) application 'Plant Gene Access'. A global overview on PGS is highly needed, the conservation strengthened, and requirement for expertise and facilities to maintain material is recommended. Not all stocks of investigated material are stored at genebanks, many of them are left on shelves in research laboratories and institutes and are sentenced to death. Morten Rasmussen explained activities to improve this situation in the European Cooperative Program for Plant Genetic Resources (ECPGR) network and NordGen participation in connection with different slides. A questionnaire was set up in some working group meetings demonstrating the situation regarding barley genetic stocks. This will be sent to different gene banks and institutes keeping genetic stocks, and will also be distributed to the participants of this workshop. He asked for feedback especially on the definition of barley PGS, the content,


organization and wording of the questionnaire and contacts to potential holders of the PGS. For the first it is of great importance that the definitions are well formulated, agreed, and they must cover the priority for conservation. It is absolutely necessary to find a long term funding for this purpose. Secondly the barley community should provide material as much as possible, high quality and an excellent feedback to show the potential use of different PGS for the correct priorities as not all material can be conserved. At last all workshop participants are strongly asked to provide all information and feedback to NordGen and send it to Agnese Kolodinska-Brantestam with e-mail address agnese.kolodinska@nordgen.org.

The final speaker was *Duane Falk*, Guelph, Canada, who attended the workshop later. He explained about his work with plant genetic resources (PGR), especially barley genetic stocks conferring male sterility. They have become the base of his breeding program and allowed the development of an efficient university program. 42 commercial cultivars were released during the years with a minimum of input. Today 50% of Ontario's agricultural area is planted with cultivars from this program. The key factor of this was that by using male sterility and recurrent selection, plant genetic resources (PGR) have been incorporated into an adapted background and allows the value of traits to be recognized. A lot of valuable traits are saved in non-adapted material in genebanks, only by evaluation in adapted backgrounds in target environment can it be exploited. Falk strongly urged to follow this strategy. If we do not do so, genebanks merely become a dusty museum!

After all introductary papers the workshop was open for discussion.

Gunter Backes from Copenhagen University – Science, Denmark asked about the purpose of the questionnaire presented by Morten Rasmussen. He replied that this questionnaire would provide a global overview on conservation status and access to barley PGR and give the base for a global strategy in the Plant Gene Access project.

Robbie Waugh stated that the barley community really needs genebanks to maintain genetic stocks. The different research institutes only maintain working collections and are not able to work with conservation.

Morten Rasmussen stressed that the scientific community should obviously participate and join in applications and developing projects.

Robbie Waugh initiated a short discussion on possibilities of charging users a fee for the access to BGS. *Kozuhiro Sato*, Kurashiki, Japan, shortly described the situation at the Japanese genebanks and Morten Rasmussen the situation at NordGen. *Ahmed Jahoor*, Nordic

Seed, Denmark, stressed that a strategy for long term conservation of global BGS must soon be found, not only for secure seed conservation, but also access to information and expertise.

Jerry Franckowiak, Australia, stressed that the barley community has a joint responsibility to secure BGS and PGR. Mutants that are developed must be taken care of, descriptions made and they must be available.

Again topics and future of Barley Genetics Newsletter (BGN) were brought up for discussion.

Jerry Franckowiak opened a new discussion in this matter. *Mats Hansson* gave a short summary of the discussions and outcome of the linkage group workshop held last Sunday night of this 11 IBGS Symposium. The Newsletter should develop to a BGS newsletter providing mainly BGS descriptions, but also getting a forum for short research reports to be published and be valuable for the barley community. *Franckowiak* urged also for an update of BGN volume 26 providing one volume containing all updated descriptions of BGS; however, this will require a lot of work. *Udda Lundqvist* commented that this would be practicable. *Mehmet Cakir*, Australia, stated that it would be of more importance and need to have an online portal providing access to a continuous updated list of the described BGS. Publishing in BGN is not of much value for researchers. *Morten Rasmussen* stated that very few researchers are publishing in BGN because of the low impact factor. Therefore it is necessary to start with something useful. If no changes are made, BGN will continue in its poor way.

Gary Muehlbauer St. Paul, USA, stated that it is more than ever important to send information data to the gene banks to keep it always updated. But *Morten Rasmussen* replied that it is a too large load for genebanks to provide a continuously updated stock list. Participation in developing a community tool should be taken into consideration and would secure maintenance of the descriptions in a readable format in the future.

Jerry Franckowiak stressed that recommendations should be made to the International Organizing Committee (IOC) of the International Barley Genetics Symposium (IBGS) to change the format of Barley Genetics Newsletter (BGN), either into a Newsletter with descriptions of Barley Genetic Stocks (BGS) and short reports as has been discussed earlier or establish a sub-committee to develop a proposal and postpone decisions to the next 12 IBGS symposium in 2016. *Bill Thomas*, Dundee, Scotland, concluded then that BGN essentially would become a Barley Genetic Stocks (BGS) newsletter. *Franckowiak* agreed with the provision that also possibilities for publication of short notes will be made. *Waugh* asked if the decision would be made immediately. *Jerry* confirmed this but if it does not work, the decision can be changed in four years. After these discussions a vote was made where about 20 participants voted for it and no one objected. The proposal will be presented to the IOC.

Barley Genetic Stocks Committee.

Udda Lundqvist reported shortly on outcomes from the Sunday evening workshop on ‘linkage groups and collections’. It became decided that barley chromosome coordinators will not be needed any more as the development of genetic markers is emerging so fast. However the coordinators of the collections will continue. She then asked the participants whether a Barley Genetic Stocks advisory board or committee should be established. This was briefly discussed.

Jerry Franckowiak suggested a BGS committee should be established under the coordination of coordinators of BGS. *Michele Stanca* added that this should be put into a motion and forwarded to the IOC. A vote was made, about 15 participants voted for and nobody opposed.

The General Coordination.

Jerry Franckowiak raised as a last item the question of an all-over BGS coordinator and proposed Udda Lundqvist to continue. This was agreed unanimously. She accepted the nomination but added that she would finally need some assistance. *Morten Rasmussen* noted that NordGen will assist her in the work for the next couple of years. However a more permanent solution should then be looked for.

Udda Lundqvist thanked the participants for attention and closed the workshop.